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<b>Subject</b>	Identification of Candidate Technologies for Treatability Studies	<b>Project Name</b>	San Mateo Creek Basin Groundwater Site: Central Study Area Remedial Investigation/ Feasibility Study
<b>Attention</b>	Daniel Lattin, P.E. Project Management Committee Chair San Mateo Creek Basin Central Study Area Working Group	<b>Project No.</b>	D3351400
<b>From</b>	Jeffrey Minchak/Jacobs		
<b>Date</b>	March 16, 2021		

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## 1. Introduction

The purpose of this memorandum is to identify a focused list of candidate treatment technologies that includes those that may be required to support the development, screening, and evaluation of groundwater treatment alternatives during the feasibility study (FS) and to describe whether treatability studies are expected to be necessary to complete the FS. This memorandum also summarizes groundwater chemistry data needed for each technology to facilitate the preparation of the site sampling and analysis plan.

Technology identification began with a review of existing groundwater characterization data within the Central Study Area (CSA), with an emphasis on concentrations of constituents of potential concern (COPCs), against potential remedial action levels for those COPCs. Generation and further analysis of the working list of COPCs that was established for the CSA is presented in the conceptual study area model (CSM) (Jacobs, 2021) that is being constructed in parallel with this memorandum. Using this working list of COPCs, treatment alternatives involving potential location-based response actions were identified for each COPC; these include in situ treatment for hot spots, point-of-use (PoU) treatment, and pump and treat (P&T) operations.

Section 2 of this memorandum describes the approach used to define potential remedial action levels, reviews existing groundwater characterization data, and determines the need for treatability studies. Section 3 summarizes the findings and conclusions if treatability studies are needed to support the FS.

## 2. Approach

Establishing technically defensible background concentrations for the alluvial and bedrock groundwater system will be an important aspect of the remedial investigation (RI) and will provide a more robust basis for COPC identification. Although a detailed analysis of background concentrations has yet to occur, COPCs were identified within the CSM based on prior work and current objectives (Jacobs, 2021). These COPCs are uranium, selenium (Se), molybdenum (Mo), thorium, radium 226+228, sulfate, chloride, nitrate, and total dissolved solids (TDS). CSM Tables 6-3, 6-4, and 6-5 list alluvial and bedrock groundwater quality data along with a comparison to a preliminary principle action level (PAL) for each COPC. These values were used to assess potential concentrations of each COPC requiring treatment and the potential treatment goals to identify candidate treatment technologies. This assessment used the

# Memorandum

## Identification of Candidate Technologies for Treatability Studies

reported dissolved concentrations. The reported total concentrations were not used because they can be appreciably affected by well construction, development, and sampling procedure and, therefore, are potentially not likely representative of concentrations mobile in groundwater requiring treatment.

The PALs used to assess potential treatment goals were the U.S. Environmental Protection Agency (EPA) primary maximum contaminant levels (PMCLs) for drinking water and New Mexico Water Quality Control Commission (NMWQCC) groundwater and irrigation standards. To keep this analysis conservative, PMCLs were included because the use of groundwater as drinking water is expected to represent the highest beneficial use and requires the highest degree of treatment. Also, a preliminary review of state and local groundwater and irrigation standards was conducted, and it was determined that various state standards may be more stringent than PMCLs for specific constituents. The most stringent standard was selected as the potential treatment goal. It should be noted that if less stringent treatment requirements are deemed appropriate for other beneficial uses, such as livestock watering or irrigation, during the identification of Applicable or Relevant and Appropriate Requirements, the list of technologies identified in this memorandum are expected to remain viable, although the degree of treatment may be less.

Based on the working list of COPCs, the most relevant treatment technologies that could be used to reduce COPC concentrations to less than the identified treatment goals were identified. Consideration was given to the most relevant treatment in terms of effectiveness, scale of use, implementability, and application within the water treatment industry.

After the list of technologies was developed and screened against the criteria presented above, the engineering information required to apply the technology in development of FS alternatives was identified to determine whether treatability studies will be needed and to assure appropriate groundwater chemical characterization is obtained during the RI.

### **3. Identification of Treatability Study Needs**

#### **3.1 Working List of COPCs**

Table 1 presents the preliminary PAL for each COPC and the maximum groundwater concentration for each reported in Tables 6-3 and 6-4 of the CSM report. These maximum concentrations were used to help assess the applicability of identified treatment technologies. While thorium was identified as a COPC in the CSM report, it is not included in this list because it was not detected above detection limits based on the current available groundwater data set.

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Table 1. Working List of COPCs, Preliminary Treatment Goals, and the Maximum Detected Concentration within Representative Groundwater Quality Data for the CSA

COPC	Preliminary Treatment Goal	Standard <sup>1</sup>	Maximum Detected Concentration <sup>2,3</sup>
<b>Inorganics and Metals (mg/L)<sup>4</sup></b>			
Mo	1	State Irrigation Standard	0.07
Se	0.05	EPA PMCL	<b>0.659</b>
Uranium	0.03	EPA PMCL	<b>0.3</b>
<b>Radiological (pCi/L)<sup>4</sup></b>			
Ra-226 + Ra-228	5	EPA PMCL	<b>8.3</b>
<b>General Chemistry (mg/L)</b>			
Chloride	250	State Groundwater Standard	<b>24,000</b>
Nitrate as N	10	EPA PMCL	<b>19.1</b>
Sulfate	600	State Groundwater Standard	<b>2,500</b>
TDS	1,000	State Groundwater Standard	<b>3,430</b>

Notes:

1. EPA PMCLs are the highest level of a contaminant allowed in drinking water. PMCLs are enforceable standards. The State Groundwater and Irrigation standards are based on NMWQCC Groundwater Standards (New Mexico Administrative Code 20.6.2.3103.A & B) and Irrigation Standards (New Mexico Administrative Code 20.6.2.3103.A, B & C).
2. Maximum detected concentration as reported in the CSM report (Tables 6-3, 6-4, and 6-5).
3. Bolded italic entries identify COPC concentrations that are greater than the preliminary treatment goal.
4. mg/L= milligram(s) per liter; pCi/L = picocurie(s) per liter

## 3.2 Identification of Treatment Technologies

Potential treatment technologies were identified for each COPC based on Jacobs in-house treatment expertise, review of current literature, existing treatment experience at the Homestake Mining Company of California (HMC) Mill site, existing PoU treatment within the CSA, and EPA best available technology information.

Table 2 lists each COPC alongside potential treatment technologies with consideration given to the following:

- Where technologies may be applied, such as in situ or ex situ
- What degree or scale the technology may be applied
- The status of each technology in terms of how well developed it is in the water treatment industry

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Table 2. Candidate Treatment Technologies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
Mo	Chemical Precipitation	P&T	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>The Mo anion (molybdate (<math>\text{MoO}_4^{2-}</math>)) is the most likely form of dissolved Mo in groundwater, and chemical precipitation is accomplished by lowering the pH of the groundwater to about 4 to 4.5 and introducing ferric iron at about 20:1 molar excess; this results in the formation of a ferric hydroxide precipitate with a positive surface charge resulting in electrostatic attraction between the anion and the iron surface; inner-sphere complexes can also form between Mo and iron (Shoepfer et al., 2020).</li> <li>The precipitation of the mineral powellite (<math>\text{CaMoO}_4</math>), when shown to be present in tailing waters, controlled Mo to ~1 mg/L (Blanchard et al., 2015).</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Treatment plant with chemical storage, feed, mix tanks, clarifiers, and potentially filters. Filter press for sludge dewatering.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-known treatment chemistry. Uses readily available equipment.</li> </ul>
	Membrane Filtration (RO)	P&T or PoU	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Reverse osmosis (RO) can remove dissolved molybdenum (EPA, 1988). Reported rejections ranged between 88 and more than 98%. The efficiency depends on the specific water chemistry and membrane used.</li> <li>Pretreatment is typically required to protect the membranes and prevent fouling. The type of pretreatment required depends on the water being treated and can consist of removing solids, adding antimicrobial chemicals, removing dissolved iron and manganese, and adding an antiscalant chemical to prevent precipitation of supersaturated mineral species such as calcium carbonate and gypsum on the membranes.</li> <li>Gypsum saturation may limit recovery, likely to about 70 to 75% with an antiscalant.</li> <li>The resulting concentrate would be evaporated in a lined pond enhanced with mechanical evaporators. Eventually, the pond would require replacement and closure in place.</li> </ul> <b>Potential Systems</b> <ul style="list-style-type: none"> <li>For P&amp;T: RO treatment plant with pretreatment and brine evaporation ponds equipped with mechanical evaporators.</li> <li>For PoU: "Home size" RO package system with concentrate to drain.</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
	Ion Exchange	P&T or PoU	<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-established technology. Membranes available from many vendors. Vendors can provide performance data and projections of performance.</li> </ul>
			<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Strongly acidic cation exchange resins can be used to remove low levels of dissolved Mo. Oxyanions can be removed using strong and weak base anion exchange resins. Regeneration is often accomplished using sodium hydroxide. The regenerant stream requires further treatment or disposal, such as in a lined evaporation pond.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Ion exchange treatment system with pretreatment and regenerant treatment.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Several commercially available resins are available. Vendors can provide performance predictions based on chemistry of feed water.</li> </ul>
Radium	Chemical Precipitation	P&T	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Can be co-precipitated with the addition of a barium salt. Can be performed at elevated pH if needed to remove other dissolved metals as hydroxides. Resulting precipitate requires dewatering and disposal.</li> <li>Radium in groundwater may be a mixture of Ra-226, with a half-life of 1,599 years, and Ra-228, with a half-life of 5.76 years. When considering ex situ coprecipitation of radium with barium sulfate as a treatment technology, the sludge would be managed appropriately due to the radioactive decay of these two isotopes, and alpha particle and beta decay, and as necessary, disposed of in a properly permitted radioactive materials disposal facility. When considering in situ coprecipitation, appropriate monitoring would be required and established.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>P&amp;T: Treatment plant with chemical storage, feed, mix tanks, clarifiers, and potentially filters.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-known treatment chemistry. Uses readily available equipment.</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
	Membrane Separation (RO)	P&T or PoU	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>RO can remove dissolved radium (EPA, 1988). Reported rejections ranged 96% or higher. The efficiency depends on the specific water chemistry and membrane used.</li> <li>Pretreatment is typically required to protect the membranes and prevent fouling. The type of pretreatment required depends on the water being treated and can consist of removing solids, adding antimicrobial chemicals, removing dissolved iron and manganese, and adding an antiscalant chemical to prevent precipitation of supersaturated mineral species such as calcium carbonate and gypsum on the membranes.</li> <li>Gypsum saturation may limit recovery, likely to about 70 to 75% with an antiscalant.</li> <li>The resulting concentrate would be evaporated in a lined pond enhanced with mechanical evaporators. The pond would eventually require replacement and closure in place.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>For P&amp;T: RO treatment plant with pretreatment and brine evaporation ponds equipped with mechanical evaporators.</li> <li>For PoU: "Home size" RO package system with concentrate to drain.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-established technology. Membranes available from many vendors. Vendors can provide performance data and projections of performance.</li> </ul>
	Ion Exchange	P&T	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Can be non-selectively removed from groundwater with standard cation exchange resins, both strong and weak acid resins (Dupont, 2020). Regeneration will concentrate radium requiring management of the regenerant solution, such as evaporation in a lined pond.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Ion exchange treatment system with pretreatment and regenerant treatment.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Several commercially available resins exist. Vendors can provide performance predictions based on chemistry of feed water.</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
Se	Biological Reduction	In Situ or P&T	<p><b>Applicability Considerations</b></p> <ul style="list-style-type: none"> <li>Selenate and selenite can be biologically reduced to elemental Se, a very fine precipitate.</li> <li>Native Se (Se<sup>0</sup>) that forms through the biological reduction of selenate (Se(VI)) and selenite (Se(IV)) can undergo reoxidation in the presence of dissolved oxygen (DO); the kinetics of this reaction with oxygen, and leaching of oxidized Se, can be relatively fast (e.g., 0.034 min<sup>-1</sup>) and first order with respect to Se concentration (Ziemkiewicz et al., 2011). However, work by Ziemkiewicz et al., 2011 showed that the presence of iron minerals (specifically iron oxyhydroxides) limits Se release to retention of the oxidized Se through sorption. Biochemical reactors (BCRs) are protective against dissolution of selenite and selenate that may occur due to reoxidation. BCRs are designed with the inclusion of iron minerals that act to sorb any oxidized Se. In addition, reduced iron minerals that form in the BCR can scavenge DO and protect against Se reoxidation.</li> </ul> <p><b>Potential Systems</b></p> <ul style="list-style-type: none"> <li>Can be performed in situ by focusing groundwater through a subsurface BCR or by injecting a substrate.</li> <li>Can also be performed in an aboveground active treatment plant or passive BCR. The resulting precipitate is removed by filtration either within the media or in a subsequent filter.</li> </ul> <p><b>Technology Status</b></p> <ul style="list-style-type: none"> <li>Common treatment approach for Se. Numerous full-scale active and passive systems employed.</li> </ul>
	Membrane Separation (RO or NF)	P&T	<p><b>Applicability Considerations</b></p> <ul style="list-style-type: none"> <li>RO and nanofiltration (NF) can remove dissolved Se.</li> <li>Efficiency depends on the oxidation state and the membrane used.</li> <li>Pretreatment is typically required to protect the membranes and prevent fouling. The type of pretreatment required depends on the water being treated and can consist of removing solids, adding antimicrobial chemicals, removing dissolved iron and manganese, and adding an antiscalant chemical to prevent precipitation of supersaturated mineral species such as calcium carbonate and gypsum on the membranes.</li> <li>Gypsum saturation will limit recovery, likely to about 70 to 75% with an antiscalant.</li> <li>The resulting concentrate would be evaporated in a lined pond enhanced with mechanical evaporators. The pond would eventually require replacement and closure in place.</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>For P&amp;T: RO or NF treatment plant with pretreatment and brine evaporation ponds equipped with mechanical evaporators.</li> <li>For PoU: "Home size" RO package system with concentrate to drain.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-established technology. Membranes available from many vendors. Vendors can provide performance data and projections of performance.</li> </ul>
	Ion Exchange	P&T or PoU	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Oxidized Se (<math>\text{SeO}_4^{2-}</math>, selenate) can be removed with an anion exchange resin.</li> <li>Resin requires periodic regeneration and disposal or treatment of the spent regenerate, such as by evaporation in a lined pond similar to membrane filtration.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>For P&amp;T: Ion exchange treatment plant with pretreatment and regenerant evaporation ponds equipped with mechanical evaporators. Chemical treatment prior to ponds may be needed.</li> <li>For PoU: "Home size" ion exchange system with offsite regeneration.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Several commercially available resins exist. Vendors can provide performance predictions based on chemistry of feed water.</li> </ul>



# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
Uranium	Ion Exchange	P&T	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Anionic uranium species (for example, uranium carbonates) can be removed from groundwater using a strong base anion exchange resin.</li> <li>The resin will accumulate radioactivity and require onsite management or the regenerant or disposed resin.</li> <li>Uranium in groundwater within the CSA is likely present as U(VI) (because the groundwater typically contains DO) and in the form of an anion as the uranyl carbonate complex (<math>\text{UO}_2\text{CO}_3</math> or <math>\text{UO}_2(\text{CO}_3)_2^{2-}</math>) or as the ternary species (<math>\text{Ca}_2\text{UO}_2(\text{CO}_3)_3</math> or <math>\text{CaUO}_2(\text{CO}_3)_3^{2-}</math>) (Dong and Brooks, 2006) depending on the calcium concentration in groundwater. The charged forms of the uranium complexes can be removed from groundwater through the use of anion exchange resins; the neutral species may require pH adjustment to transition these to charged forms (e.g., pH decrease leading to the formation of the uranium <math>[\text{UO}_2^{2+}]</math> cation with removal by a cation exchange resin). Removal of uranium from acidic and also alkaline waters, and water dominated by carbonate, is well established, and ion-exchange resins have been evaluated under a variety of geochemical conditions (Rosenberg et al., 2016).</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Ion exchange treatment plant with pretreatment and regenerant treatment.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Several commercially available resins exist. Vendors can provide performance predictions based on chemistry of feed water.</li> </ul>
	Chemical Precipitation	P&T or In Situ	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Uranium can be precipitated with lime, such as by lime softening.</li> <li>Coagulation with iron or aluminum can improve removal at lower pH values.</li> <li>Resulting precipitates are settled and dewatered and would require onsite disposal.</li> <li>Uranium may also be precipitated in situ or ex situ using phosphate precipitation, forming insoluble uranium phosphate minerals (Arcadis, 2016). Best used as a treatment approach for areas within the CSA exhibiting localized elevated concentrations.</li> <li>Uranium coprecipitation with hydroxyapatite is well studied, and the result is the formation of a low-solubility form of uranium, including chernikovite and/or autunite (Arey et al., 1999).</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>P&amp;T: Treatment plant with chemical storage, feed, mix tanks, clarifiers, and potentially filters.</li> <li>In Situ: Phosphate solution preparation and injection.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-known treatment chemistry for lime precipitation. Uses readily available equipment. Considerable experience with phosphate precipitation of uranium at the HMC Mill site.</li> </ul>
	Membrane Separation (RO or NF)	P&T	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>RO and NF can remove dissolved uranium.</li> <li>Gypsum saturation will limit recovery, likely to about 70 to 75% using an antiscalant.</li> <li>Resulting concentrate would be evaporated in a lined pond and could be enhanced with mechanical evaporators. The pond would eventually require replacement and closure in place.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>RO or NF treatment plant with pretreatment and brine evaporation ponds, which could be equipped with mechanical evaporators.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-established technology. Membranes available from many vendors. Vendors can provide performance data and projections of performance.</li> </ul>
	Biological Reduction	In Situ	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Like Se, uranium could be reduced in situ.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>The same potential systems used for Se could be used for uranium.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Fewer known number of applications than for Se, but similar approaches would be used.</li> </ul>
Chloride	Membrane Separation (RO)	P&T or PoU	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Removal of monovalent chloride requires an RO membrane, such as that used to generate drinking water from sea water.</li> <li>Similar pretreatment and concentrate management considerations as described above for other RO applications.</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
Nitrate	Biological Reduction	P&T	<b>Potential Systems</b> <ul style="list-style-type: none"> <li>For P&amp;T: RO treatment plant with pretreatment and brine evaporation ponds equipped with mechanical evaporators.</li> <li>For PoU: "Home size" RO package system with concentrate to drain.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Common and widely used, such as for sea water and other high chloride waters.</li> </ul>
			<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>Nitrate is used by microorganism as an electron acceptor in the absence of oxygen; this is amenable to anaerobic biological treatment via denitrification.</li> <li>Resulting biological sludge must be dewatered and disposed of.</li> <li>Nitrate treatment through biological denitrification is a well-established technology and can be implemented through active or passive (BCR) means; although the aquifer is predominantly aerobic (microenvironments likely exist in fine-grained aquifer materials where the conditions are anoxic), and the addition of an electron donor in the form of soluble organic carbon will result in microbial activity leading to consumption of DO and nitrate. The potential for transformation of solid-phase elements (e.g., manganese or iron) in this case is limited because the treatment process is proposed to be implemented in an ex situ manner (e.g., electron donor would be added to a BCR rather than to the aquifer).</li> <li>If other COPCs are present in the groundwater undergoing treatment for nitrate, the reducing conditions established for nitrate reduction to nitrogen gas would be beneficial for treatment of uranium (with transformation from U(VI) to U(IV), Se (Se(VI)) to elemental Se) and sulfate to sulfide (if reducing conditions were established low enough to treat sulfate). The resultant reduced forms of uranium, Se, and sulfur all have lower solubility than the oxidized forms.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Active treatment plant with chemical storage and feeding, mixed tanks, clarifications, sludge dewatering, and sludge disposal.</li> <li>Passive system with BCR followed by aerobic polishing.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Common treatment approach for nutrient removal. Practiced at numerous wastewater treatment plants worldwide.</li> </ul>

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Analyte	Most Relevant Treatment Technologies	Applicable Locations	Discussion
	Membrane Filtration	P&T or PoU	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>RO or electrodialysis is effective for nitrate removal.</li> <li>Similar to prior discussion, membrane filtration will be limited by gypsum, and concentrate management will be required.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Similar to RO systems described previously.</li> <li>While ion exchange is often performed for nitrate, the high concentration of sulfate in the groundwater would interfere with removal.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-established technology. Membranes available from many vendors. Vendors can provide performance data and projections of performance.</li> </ul>
Sulfate and TDS	Membrane Filtration	P&T	<b>Applicability Considerations</b> <ul style="list-style-type: none"> <li>RO or NF membrane may be used to remove sulfate and TDS.</li> <li>Similar to prior discussion, membrane filtration will be limited by gypsum, and concentrate management will be required.</li> </ul>
			<b>Potential Systems</b> <ul style="list-style-type: none"> <li>Similar to RO systems described previously.</li> </ul>
			<b>Technology Status</b> <ul style="list-style-type: none"> <li>Well-established technology. Membranes available from many vendors. Vendors can provide performance data and projections of performance.</li> </ul>

## 3.3 Technology Information Needs for Feasibility Study

Each candidate treatment technology has specific information needs to support its use in the FS. As scoping of the RI begins, and fieldwork and sampling plans are being prepared, it is crucial that the information needed for the development of FS alternatives be understood so it can be collected during the RI. Table 3 summarizes the information that will benefit and help drive preliminary and remedial design for each candidate technology. This information falls into two categories: (1) flow rate or flux information for ex situ or in situ applications and (2) chemistry information. Note that jar testing, as needed, with a range of added chemicals is typically conducted as part of the routine design of treatment systems and implementation. Jar tests are conducted to help understand site-specific precipitation characteristics and to identify required chemical dosages; these are conducted during the treatment design phase.

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Table 3. Candidate Treatment Technology Information Needs for Feasibility Study

Candidate Treatment Technology	Potential Target COPCs	FS Information Needs
Chemical Precipitation	Mo, Radium, and Uranium	<ul style="list-style-type: none"> <li>Chemistry: Major cations, major anions, trace metals, pH, TDS, oxidation reduction potential (ORP), DO, alkalinity</li> <li>Soil characterization data to inform possible secondary reactions (for in situ treatment)</li> <li>Ex Situ: Maximum flow rate, average flow rate, minimum flow rate, rate of flow variation, residence times</li> <li>In Situ: Aerial and vertical extent, maximum flux, average flux, minimum flux, seasonal variation, aquifer properties, groundwater flow paths, solute-groundwater residence times</li> </ul>
Membrane Filtration (RO or NF)	Mo, Radium, Se, Uranium, Chloride, Nitrate, Sulfate, and TDS	<ul style="list-style-type: none"> <li>Chemistry: Major cations, major anions, trace metals including aluminum, iron, manganese, barium and strontium, fluoride, silica, pH, TDS, total organic carbons (TOC), ORP, alkalinity</li> <li>Maximum flow rate, average flow rate, minimum flow rate, rate of flow variation</li> </ul>
Ion Exchange	Mo, Radium, Se, and Uranium	<ul style="list-style-type: none"> <li>Chemistry: Major cations, major anions, trace metals including aluminum, iron, manganese, barium and strontium, fluoride, silica, pH, TDS, TOC, ORP, alkalinity, solute/adsorbate competition kinetics</li> <li>Maximum flow rate, average flow rate, minimum flow rate, rate of flow variation, residence times</li> </ul>
Biological Reduction	Se, Uranium, and Nitrate	<ul style="list-style-type: none"> <li>Chemistry: Major cations, major anions, trace metals, pH, TDS, TOC, ORP, DO, alkalinity</li> <li>Ex Situ: Maximum flow rate, average flow rate, minimum flow rate, rate of flow variation</li> <li>In Situ: Aerial extent, maximum flux, average flux, minimum flux, seasonal variation, aquifer properties, groundwater flow paths, solute-groundwater residence times, soil characterization data informing possible secondary reactions</li> </ul>

## 3.4 Determination of Treatability Study Needs

Jacobs has previous experience with removing the identified COPCs and extensive working knowledge of the presented treatment techniques. Not only are the candidate treatment techniques well-studied, documented, and used broadly throughout the water treatment industry, but also many have been used within the CSA in PoU, P&T, and in situ systems to remove similar contaminants. For example, PoU RO systems within the CSA have been shown to be effective at removing uranium and gross alpha particles found in a domestic well to below the PMCLs (EPA, 2016), an RO system has been used effectively at the HMC Mill site to treat impacted groundwater, and the HMC Mill site has used a zeolite surface adsorption water treatment system to effectively treat impacted waters (HMC, 2019). There have also been successful pilot-level studies for in situ treatment of uranium through precipitation of phosphate minerals (Arcadis, 2016).

# Memorandum

Identification of Candidate Technologies for  
Treatability Studies

Based on the advanced state-of-the-art of the candidate technologies, information available from vendors, level of experience either within the CSA or at the HMC Mill site, Jacobs in-house experience, and the expected ability to collect the necessary site information during the RI, it is concluded that treatability studies are not likely to be needed to support the FS.

Though treatability studies are not likely to be needed to support the FS, it is common after a remedy is selected to reassess the benefit of a treatability study to support and improve the remedial design. Design-level studies are focused studies that can include bench- and pilot-scale testing, such as jar tests or column studies, to derive application-specific information, such as site-specific precipitation characteristics, for a cost-effective design, if needed.

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